STUDIES ON TILAPIA AS SKIPJACK BAIT

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United States Department of the Interior, Fred A. Seaton, Secretary

Fish and Wildlife Service

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ABSTRACT

The cichlid fish, *Tilapia mossambica*, introduced to Hawaii in 1951 by the Territorial Division of Fish and Game, now has a wide distribution in the islands. During the summer of 1956, tilapia were seined from fresh-water ponds and irrigation reservoirs, acclimatized to sea water, and tested at sea as skipjack bait. The results indicated that tilapia, while inferior in some respects to the native bait (nehu), possessed many desirable qualities. It was concluded that if small tilapia could be produced in large volume at a reasonable price they might alleviate the great need in the Hawaiian skipjack fishery for additional bait supplies. The rearing of tilapia for bait purposes cannot be done most effectively, however, in the presently available ponds and reservoirs with little control over the cannibalistic traits of the species, of predation by other animals, and with the difficulty of harvesting the fish efficiently at an optimum size.

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In the spring of 1956, the Fish and Wildlife Service joined forces with the Hawaiian Tuna Packers, Ltd., in an informal arrangement for the purpose of seining supplies of young tilapia (Tilapia mossambica) and testing them as skipjack bait. This report provides a preliminary evaluation of ponds and reservoirs as a means of producing bait-size tilapia, it describes briefly the methods used in acclimatizing the fish to sea water, and adds to the available information on the qualities of young tilapia as skipjack bait.

The skipjack (Katsuwonus pelamis) is the most important commercial fish species in Hawaii. The annual catch for the 5 years, 1951-55, averaged 11,183,000 pounds, with an average annual value to the fishermen of $1,452,000. The fish are caught by pole and line using live bait as chum. The principal bait employed is nehu (Stolephorus purpureus), a small anchovy. The volume of the skipjack catch is largely governed by the bait supply (Tester 1951, Brock and Takata 1955). During the summer months at the peak of the skipjack season, the demand for bait usually exceeds the amount obtainable, so that an exorbitant amount of time must be spent by the vessel crews searching for bait.

The nehu is a delicate fish and must be handled with great care; it will survive for not more than a few days, or at most a week, in the bait boxes of the skipjack boats (sampans). Also, its life history and habitat requirements are thought to render the fish unsuitable for cultivation under artificial conditions. It was the conclusion, therefore, of biologists employed by the Territory, the University of Hawaii, and the U. S. Fish and Wildlife Service that new types of bait, either artificial or natural, were needed if the Hawaiian skipjack fishery were to expand and make better use of the available tuna resource.

During the years 1952-53, the University of Hawaii, under contract with the Fish and Wildlife Service, undertook an investigation to discover means of attracting tuna within reach of a fishing vessel through the use of artificial bait. Both edible materials (macaroni, strips of agar and fish flesh, gelatin capsules) and inedible materials (aluminum foil, tin particles, mica flakes) were tested with generally negative or inconclusive results (Tester et al. 1954).

During this same period, the Territorial Division of Fish and Game was successful in developing improved methods of holding bait fishes with greatly reduced mortality (Brock and Takata 1955), and as early as 1951, the Territory had taken steps to introduce a new species of fish adaptable to pond cultivation and possibly suitable as a bait fish. The problem of bait-fish mortality is receiving further study by the Hawaiian Tuna Packers, Ltd. with the aim of conserving the natural bait supply.

Tilapia mossambica, a cichlid fish native to East Africa, was brought to Hawaii in 1951 from the East Indies, where in a short period of years it had become a popular food fish. The Territorial Division of Fish and Game received a shipment of 60 fry from the Singapore Fisheries Commission in December 1951 (Brock and Takata 1955). The 15 survivors of this original lot multiplied prodigiously and today the species is well established in private and commercial fish ponds on the major Hawaiian Islands.

Tilapia were introduced to Hawaii with the expectation from what was known of their food habits that they would be useful in the control of algal growth in water reservoirs. It was hoped also that the young of the species might prove to be satisfactory live bait for use in the skipjack fishery, and that the adults would fill a need for additional food fish.

Because of their widespread popularity as food fish in Africa and east Asia, a wealth of information is available on the culture and biology of the various species of Tilapia (Chimits 1955). We shall not attempt a general review of the literature in this brief report. It may suffice to state, however, that the species *T. mossambica* is a "mouth breeder", or more properly a "mouth brooder"; i.e., immediately after spawning and fertilization have taken place, the female picks up the eggs in her mouth and, following hatching of the eggs in about 60 hours, she continues to carry the young in her mouth cavity for another 5 to 8 days (Chen 1953, Chimits 1955).

The relatively low number of eggs spawned (100 to 1,000 in *T. mossambica*), the number depending largely on the size of the female (Chen 1953), is compensated for by this special care of the young and by a high frequency of spawning, so that the fish actually have a high reproductive potential. These positive factors are partially offset, however, by the susceptibility to predation of the newly released young and by cannibalistic tendencies in both adult fish and juveniles. The growth of the young fish is quite rapid; they attain a suitable bait-fish size (1-1/2 to 2 inches) for skipjack fishing in about 2 months. The adults reach a maximum size of about 12 inches and 1-1/2 pounds.

The first sea tests to evaluate tilapia as skipjack bait were conducted by the Territorial Division of Fish and Game in the summer of 1954. On 2 of 5 trials no skipjack schools were encountered; on the remaining 3 trials fish were taken by using nehu to attract the skipjack school to the stern of the boat and then switching to tilapia during the fishing. The conclusions were that although some of the tilapia tended to sound --which is an undesirable trait in a bait fish-- they were adequate in most respects.

It still remained to be demonstrated, however, that tilapia were equal to nehu in the ability to attract and draw in a tuna school to a fishing position at the stern of the vessel. The principal objectives of the present study were to gain a more thorough evaluation of tilapia as skipjack bait and, by conducting most of the tests on the commercial vessels, to introduce the new bait to the sampan fishermen and obtain their opinions and reactions.

SEINING TILAPIA

In March 1955, the Hawaiian Tuna Packers took over the management of one pond which had been stocked by the Territorial Division of Fish and Game, and shortly thereafter they stocked three additional ponds; all are fresh-water ponds located on the Ewa Plantation, Oahu. The ponds vary in size from 1-1/2 to 4-1/2 acres and in depth from 3 to 13 feet. Since they serve as storage reservoirs for irrigation purposes, they are subject to widely fluctuating water levels. Before the introduction of tilapia some of the ponds were badly choked with filamentous algae. This was cleaned out by the tilapia in less than 6 months and since then the ponds have remained clear of vegetation.

The fish were supplied with a variety of locally available feeds, including a mixture of pineapple stump meal and stickwater from the fish processing plant, rice bran, stale bread, ground stale bread mixed with fish meal, and ground crayfish which had been removed from the ponds.

In only one pond (pond No. 6) was there successful reproduction during the summer of 1956. Another of the ponds (pond No. 9) contained a large population of adult fish but there was little or no production of young fish. In two other ponds (ponds No. 3 and No. 5) the tilapia did not establish themselves following the initial stocking and apparently disappeared. Pond No. 5 has been recently restocked.

During the period from May to September, 1956, the two collaborating organizations (POFI and Hawaiian Tuna Packers) conducted 7 full-day and 2 half-day seining operations to obtain supplies of small bait-size tilapia for testing purposes. In addition to the No. 6 pond at Ewa, some tilapia were obtained from a 3-acre brackish-water pond and from 2 small pools, all on the outskirts of Honolulu. A 40-fathom "nehu" net was used in seining the larger ponds, and a 10-fathom net was used in the smaller pools. In making a set with the 40-fathom seine, the net was first stacked on a rubber life raft (turned bottom up) and then pulled from the raft as it was towed across the pond (figs. 1 and 2). In the larger ponds, a Japanese-type bait-holding device ("kowari"), somewhat modified in structure, was used in sorting the fish according to size and for holding the bait-size fish until the end of each day's seining, when they were transferred to drums of water and transported by truck to the fishing docks. The water was aerated during the trip. With this method there was essentially no mortality among the tilapia as the result of handling or while in transit, except among the small fish less than 1 inch in length.

Table 1 shows the pounds of small (<3"), medium (3 - 8") and large (8 - 12") tilapia

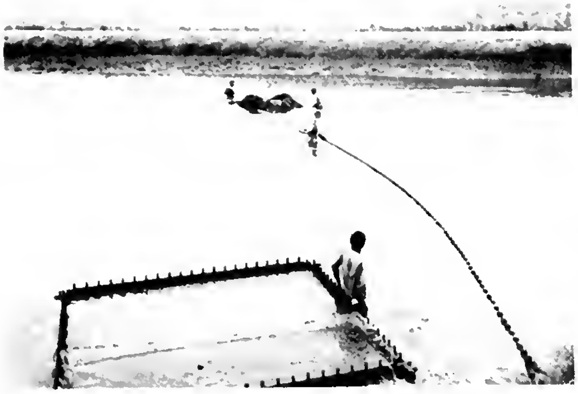

Figure 1.--Start of a seine haul in the No. 6 pond. The "kowari", a Japanese bait-holding device, is shown in the foreground.

Figure 2.--Completion of a seine haul in the No. 6 pond.

captured on each day's seining. In each instance the small fish were retained alive for use as bait, the medium-size fish were returned to the pond, and the large fish were retained, usually alive, for sale on the fresh-fish market. It is evident from table 1 that the main source of tilapia was pond No. 6, which was seined on five occasions and yielded a total of 436 pounds of bait-size fish and 847 pounds of market fish in a period of about 4 months. In all, 634 pounds (90 "buckets") of small tilapia were obtained for the sea tests.

Water reservoirs, such as those on the Ewa Plantation, do not provide optimum conditions for rearing tilapia. The water is constantly being replaced so that there is little opportunity for natural foods, in the form of filamentous

Table 1.--Results of tilapia seining operations in various ponds near Honolulu

Pond	Pond area	Date	Small, <3"	Medium, 3 - 8"	Large, 8 - 12"	Number of hauls
			lbs.	lbs.	lbs.	
No. 6 (Ewa)	3.85 acres	5/18/56	175	255	84	4
Do.	do.	6/22/56	80	246	68	7
Do.	do.	7/ 6/56	56	497	272	8
Do.	do.	8/ 3/56	55	683	381	8
Do.	do.	9/ 7/56	70	398	42	5
		Subtotal	436	2,079	847	32
No. 9 (Ewa)	4.50 acres	5/10/56	3	339	152	5
Kuliouou	3.00 acres	7/10/56	105	541	81	5
Wong's	60 x 60 feet	7/20/56	80	-	-	-
Waimano Home	Dia. 23 feet	8/ 2/56	10	47	-	1
		Subtotal	198	927	233	11
		Total	634	3,006	1,080	43

algae and plankton, to develop. The ponds were not constructed to permit complete drainage and proper harvesting of the fish crop. Seining required a rather large labor force and was not very efficient since the fish tended to burrow in the mud or to hide in the spawning beds (fig. 3)

Figure 3.--Spawning beds or depressions produced by male tilapia.

or other depressions in the pond bottom. Fish of all sizes were obtained in each haul so that sorting, although greatly simplified by means of the "kowari", was still a problem. A crew of seven men was used in each day's seining operations on the No. 6 pond. At an approximate wage of $15 per man-day the 436 pounds of bait obtained cost $1.20 a pound for labor alone. It was evident that tilapia culture for the object of producing large quantities of bait-size fish could only be a profitable enterprise under more efficient and more fully controlled conditions.

ACCLIMATIZATION OF TILAPIA TO SEA WATER

Since the tilapia had been reared in fresh or slightly brackish water they required a short conditioning period before being subjected to the high salinity of the open ocean. This acclimatization process was achieved by two methods. One involved the use of shoreside tanks provided with fresh- and sea-water inlets. Over a 10-hour period the flow of fresh water was reduced while sea water was introduced in increasing amounts. In the other method, the acclimatization took place directly in the bait boxes of the sampans while they were docked in Kewalo Basin, a salt-water harbor. The bait-holding compartments of these vessels have no forced circulation system but open directly to the sea through ports in their bottoms which may be plugged if desired. The boxes were filled with fresh water prior to the introduction of the fish. The fresh water was then gradually replaced with sea water by opening the ports in the bottom of the box and reducing the inflow of fresh water. A complete exchange could be produced in about 10 or 12 hours.

In observing the fish during acclimatization we saw few signs of distress until the salinity reached 22 to 24‰. At this point the fish became sluggish in their movements and tended to congregate at the surface. If the salinity were increased rapidly beyond this level mortality was likely to occur, but if the fish were held for perhaps 2 hours at this salinity they could then be moved through increasing salinities to pure sea water with little loss.

Brock and Takata (1955) state that young tilapia may be transferred directly from fresh water to water of 18‰ with no ill effects. We have not as yet carried out experiments to determine the most efficient method for effecting the acclimatization, but it is our belief that no serious problems are involved and that the process can be accomplished with little loss of bait or of vessel time.

RESULTS OF SEA TESTS

During the summer of 1956, the effectiveness of tilapia as skipjack bait was examined on 14 vessel-days at sea in waters off Oahu, employing tilapia seined in the operations described above. All tests were observed and directed by personnel of Hawaiian Tuna Packers and the Fish and Wildlife Service. The government research vessel Charles H. Gilbert was used on 2 days. The remainder of the tests were conducted aboard sampans of the local skipjack fleet; those vessels taking part are listed in table 2. We are glad to acknowledge our indebtedness to the vessel owners and captains for their helpful participation in these studies.

Since it had been established by Brock and Takata (1955) that tilapia could be used to catch skipjack if the schools were first chummed-up with nehu, it was the prime objective of these present tests to determine the ability of tilapia to attract and hold schools in a fishing position without support from nehu. We hoped to observe and compare the response of skipjack schools to both nehu and tilapia when used independently.

Table 2. --Vessels and observers taking part in sea tests of tilapia, summer 1956

Vessel	Captain	Date	Observers
Neptune	Y. Teramae	5/22/56	P. Wilson, J. King
Do.	do.	5/23/56	P. Wilson, J. King
Do.	do.	5/24/56	P. Wilson, D. Yamashita
Orion	M. Sarae	6/21/56	P. Wilson, H. Yuen, R. Henrickson
Do.	S. Seki	6/26/56	P. Wilson, J. King
Charles H. Gilbert	W. Tanaka	7/11/56	A. Tester, P. Wilson, J. King, H. Yuen, R. Shomura
Do.	do.	7/12/56	A. Tester, P. Wilson, J. King, H. Yuen, R. Shomura
Marlin	K. Asari	7/26/56	P. Wilson, J. King
Do.	do.	7/27/56	P. Wilson, J. King
Buccaneer	N. Tsue	8/10/56	P. Wilson, J. King
Do.	do.	9/19/56	P. Wilson, H. Yuen, H. Shippen
Do.	do.	9/20/56	P. Wilson, H. Yuen, H. Shippen
Do.	do.	9/21/56	P. Wilson, H. Yuen, H. Shippen
Do.	do.	9/22/56	J. King

Because of circumstances beyond the control of the observers it was not always possible, however, to have the two baits used in a manner to provide the desired information. Due to the general excitement of the fishing operation when the vessel was in contact with a school, and the great desire of the fishermen to catch every fish possible, the experiment was not always conducted according to the design. On a few days, as might be expected, no skipjack schools were encountered.

The results of each day's fishing are shown in table 3 and summarized in table 4. The data are quite variable and difficult to evaluate. The best fishing experienced during the tests was that of the Neptune on May 22, when no tilapia were used, and that of the Orion (fig. 4) on June 21 and June 26, when we were furnished with an excellent opportunity to compare the effectiveness of the two baits. On June 21 about 21,000 pounds of skipjack were caught from two schools at a rate of 9.8 fish per minute and 30 fish per bucket of bait using nehu, as against 5.9 fish per minute and 12 fish per bucket of bait using tilapia. On June 26, about 19,800 pounds of skipjack were caught from five schools at the average rate of 7.4 fish per minute and 31 fish per bucket of bait using nehu, and 7.6 fish per minute and 23 fish per bucket of bait using tilapia.

When nehu and tilapia were employed in fishing the same school, there was no noticeable difference in the behavior of the skipjack when the chummer switched from one bait to the other. Figure 5 shows the variations in catch rate using the two baits on a slow-biting school (upper panel), and with a fast-biting school (lower panel).[1/]

The fishermen remarked on the "hard-biting" quality of the skipjack schools when tilapia were being used as bait. This biting behavior is a favorable reaction in the fishermen's opinion since it is obtained with nehu during the periods of best fishing. Other substitute bait fish such as top minnows or mosquito fish (*Limia*, *Mollienesia*, *Gambusia*) do not evoke this response in skipjack and are not used by the Hawaiian fishermen unless there is an extreme scarcity of nehu.

In the general summary of the results (table 4) it is shown that 21 (56 percent) of the 37 schools first chummed with nehu surfaced and responded to the bait; also that 10 (56 percent) of the 18 schools first contacted with tilapia gave a favorable response to the bait. Skipjack were caught from 9 schools at the rate of 3.5 fish per minute and 12.2 fish per bucket of tilapia used. This is not quite as good as the catch rate, 4.8 skipjack per minute and 15.3 per bucket of bait, obtained with nehu from 23 schools, but there is every reason to believe that, with experience, chummers will learn to use the new bait more effectively.

[1/] This method of depicting the catch rate was devised by H. S. H. Yuen of POFI for use in studying the biting behavior of skipjack schools.

Table 3. --Results of sea tests to compare nehu and tilapia as skipjack bait

Vessel	Date, 1956	Bait	Schools chummed 1/	Schools chummed first with	Schools surfacing first to	Schools fished 2/	Time fished (minutes) 3/	Skipjack catch (number)	Skipjack catch (number) per minute of fishing 3/	Amount of bait used (buckets) 4/	Skipjack catch (number) per bucket of bait used 4/
Neptune	5/22	Nehu	10	10	6	6	41	366	8.9	10	36.6
		Tilapia	-	-	-	-	-	-	-	-	-
Do.	5/23	Nehu	1	1	1	-	-	-	-	8	-
		Tilapia	-	-	-	-	-	-	-	-	-
Do.	5/24	Nehu	5	5	2	2	17	48	2.8	10	4.8
		Tilapia	-	-	-	-	-	-	-	-	-
Orion	6/21	Nehu	3	2	2	2	93	911	9.8	30	30.4
		Tilapia	3	1	-	2	10	59	5.9	5	11.8
Do.	6/26	Nehu	10	7	2	4	85	627	7.4	20	31.4
		Tilapia	3	3	1	3	36	275	7.6	12	22.9
Charles H. Gilbert	7/11	Nehu	8	4	3	4	24	56	2.3	16	3.5
		Tilapia	6	5	4	-	-	-	-	8	-
Do.	7/12	Nehu	-	-	-	-	-	-	-	-	-
		Tilapia	2	2	1	-	-	-	-	2	-
Marlin	7/26	Nehu	5	5	3	3	52	86	1.7	14	6.1
		Tilapia	2	1	1	2	20	31	1.6	4	7.8
Do.	7/27	Nehu	1	1	1	1	29	72	2.5	10	7.2
		Tilapia	1	-	-	1	49	93	1.9	5	18.6
Buccaneer	8/10	Nehu	2	2	1	1	4	12	3.0	5	2.4
		Tilapia	4	4	2	1	3	1	0.3	8	0.1
Do.	9/19-21	Nehu	-	-	-	-	-	-	-	-	-
		Tilapia	-	-	-	-	-	-	-	-	-
Do.	9/22	Nehu	-	-	-	-	-	-	-	-	-
		Tilapia	2	2	1	-	-	-	-	2	-

1/ On several schools chummed both bait species were employed.
2/ Schools from which fish were caught using each bait.
3/ Includes only the time on schools from which some fish were caught.
4/ Based on the total amount of bait used on all schools chummed regardless of catch.

With few exceptions all of the skipjack caught were "season" fish of 20 to 28 pounds, ranging in length from about 70 to 80 cm. One of the skipjack caught while using tilapia as bait is shown in figure 6 along with the contents of its stomach, demonstrating that skipjack find tilapia acceptable as food.

In the Hawaiian pole-and-line fishery, the school is worked with the vessel underway at a speed of about 3 knots. During our tests it appeared that, when using tilapia as bait, the best results were obtained when the vessel was slowed to about 2 knots.

We learned also that tilapia of 1-1/2 to 2 inches in length are of an optimum size for skipjack bait. It was observed that a large percentage of the tilapia 3 to 4 inches in length sound when used as chum. This trait was previously reported by Brock and Takata (1955). The smaller fish, however, stay near the surface and attempt to school with the vessel--characteristics of a good bait fish. The diving tendency of the larger

Table 4.--Summary of results obtained with nehu and tilapia in fourteen days of sea tests

	Nehu	Tilapia
Total schools chummed[1]	45	23
Schools chummed first with	37	18
Schools surfacing first to	21	10
Total schools fished[2]	23	9
Total time fished (minutes)[3]	345	118
Average number of skipjack caught per minute of fishing[3]	4.8	3.5
Average number of skipjack caught per bucket of bait used[4]	15.3	12.2

1/ Several schools were chummed employing both bait species.
2/ Schools from which fish were caught using each bait.
3/ Includes only the time on schools from which some fish were caught.
4/ Based on the total amount of bait used on all schools chummed regardless of catch.

fish may not be a detrimental factor when fishing a fast-, hard-biting school which gives the bait little opportunity to sound. Another feature favoring the smaller tilapia is the weak development of the spines in the dorsal and anal fins. In the larger fish these spines are sufficiently well developed to cause some injury to the chummer's hands if he "squeezes" the bait to lessen its activity.

Figure 4.--The results of skipjack fishing on the Orion, June 26, 1956, using both nehu and tilapia as bait.

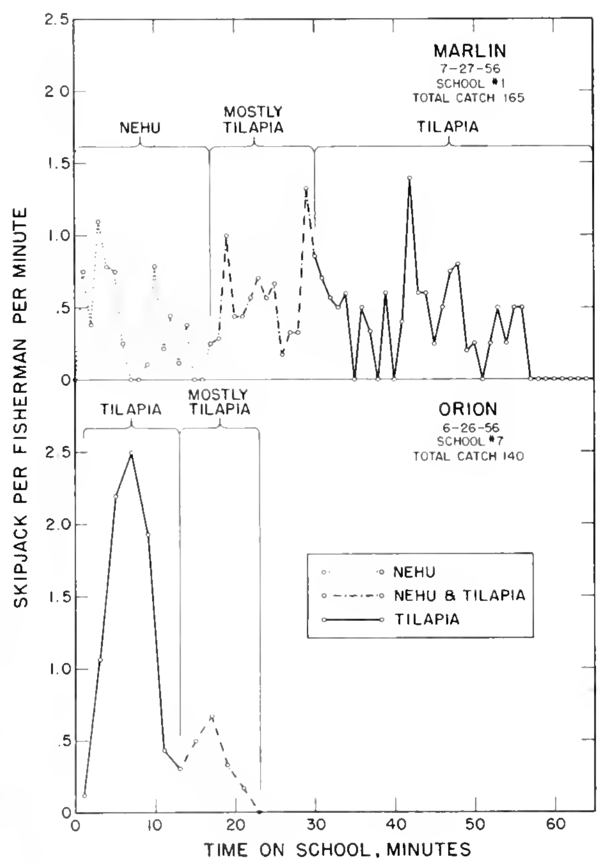

Figure 5.--Variations in catch rate when using nehu and tilapia to chum a slow-biting school (upper panel) and a fast-biting school (lower panel).

Figure 6.--Skipjack caught by pole and line using tilapia as bait, with the stomach opened to show the numerous small tilapia among the stomach contents.

In some respects tilapia may be slightly inferior to nehu, but, on the other hand, they have several compensating qualities. They are exceedingly hardy fish; they can survive handling and crowding in bait boxes that the nehu cannot tolerate. They can live in a wide range of salinities, in low oxygen concentrations, and can be held for indefinite periods in confined quarters. Some information has been obtained indicating that tilapia can be starved and thus held at an optimum bait size for prolonged periods. Nehu will seldom live longer than a week in the bait boxes of the sampans and frequently die of unexplained causes within a day or two after capture.

CONCLUSIONS

It is our conclusion that young of Tilapia mossambica are an adequate bait fish for catching skipjack. Our observations indicate that tilapia have a sufficient number of the desirable qualities of a good live-bait fish to alleviate the great need in the Hawaiian skipjack fishery for additional bait supplies, provided they can be produced in sufficient amount at a price the industry can afford. If, through supplementing the present nehu supplies with a substitute bait species, the average fishing time for a sampan can be increased from the present 15 days a month to 20 days a month, the total annual skipjack catch for the Territory might be increased by 3 to 4 million pounds.

At this point it does not appear that the rearing of tilapia for bait purposes can be done most effectively in water reservoirs and natural ponds with little control over spawning, cannibalistic traits of the species, and predation, and with the difficulty of harvesting the fish efficiently at an optimum size. If it is accepted that tilapia are the most promising bait fish to supplement the nehu, then it would appear that studies are needed to determine the economic aspects of rearing these fish in the needed quantities under controlled conditions.

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